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Curiosity and Languages

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In a big egg that has just opened, a tribe of young robotic creatures evolves and explores its environment, wreathed by a large zero that symbolizes the "origin." Their movements and the sounds they produce can be likened to those of biological beings. They are equipped with a certain number of innate perceptual, motor and cognitive abilities. For example, they are sensitive to movement and to certain colors. They go to sleep when their motors become overheated. They are also outfitted with mechanisms that allow them to learn and to share things that are new to them, thus enabling them to expand their horizons with regard to their behavioral and cognitive skills.

To begin with, they are able to explore their bodies and the relationship between these bodies and their surroundings in an entirely autonomous way: they are endowed with artificial curiosity. They experiment physically with the objects around them, toys such as balloons or bells, driven by nothing more than the desire to acquire new information: they push or toss the objects, watching to see whether this will make them roll, jump or, for example, produce sounds. They start off by showing interest in the objects and actions that their artificial brains can easily learn to model. Once these objects and actions have been mastered, they explore other more complex activities for no other reason, once again, than the pleasure of learning.

The creatures also play "language games" in pairs, inventing (through the use of their innate cognitive mechanisms) and exchanging words and new meanings that enable them to share the same concepts and to speak about objects and events in their environment or skills they have picked up through the exploration process. At first, their vocabulary and semantic repertoires are empty, but they gradually develop, become synchronized, self-organized, and an elementary but entirely original linguistic system is born.

Finally, a window of interaction with the world of humans allows human beings to make gestures or movements that may be perceived and imitated by the creatures. This interaction expands their motor repertoire and leads them to create words and new meanings in order to talk about these movements among themselves.

Description of the experimental installation Ergo-Robots / Flowers Fields

The morphogenesis of behavioral and cognitive structures, which may be observed, for example, in human children during their first years of life—becoming acquainted with their bodies, with their environment and the first rudiments of language—is the focus of my scientific work. In fact, that is what led me, out of curiosity, into research. I came to this field, which would seem to be situated between the social sciences and the life sciences, in a rather unorthodox way: I design and experiment with machines, particularly robots, whose purpose is to model these processes of morphogenesis. Alan Turing had suggested using this kind of approach back in the 1950s when he demonstrated how computers could be used to help us model and better understand the self-organization processes of elementary physical and chemical structures. This approach then became very influential in certain areas of biology and ethology, for example, to develop models of how termite nests are built. For the past twenty years, a certain number of researchers around the world, including myself, have been attempting to apply this approach, via the use of robots, to the creation of models in the areas of child development and the formation of cultural structures such as natural languages.

This is the framework within which *Flowers Fields* was designed. It is the result of the work I have done with colleagues and students at INRIA and the University of Bordeaux. It is both a scientific experiment and an installation that promotes interaction between scientists from different disciplines, as well as between scientists and non-scientists. In addition, it developed out of two previous experiments: *The Talking Heads Experiment*, which was conducted by Luc Steels and which showed for the first time, on a large-scale, how a society of robots could invent a language, and *The Playground Experiment*, which I designed with Frédéric Kaplan and which demonstrated that a robot could be endowed with artificial curiosity and learn new skills both on its own and in an "open-ended" way.

The most complex entities in the known world are probably the brain, interacting dynamically with the body and its physical and social environment, and the behaviors and structures that result from these interactions. Scientific research in these areas is still quite young. It is not more than a few centuries old. Huge scientific challenges lie ahead, and I believe that it is precisely because of the complexity of the phenomena involved—in the sense of the "sciences of complexity"—that it is useful, for many different reasons, to build machines.

Scientific research does not only consist of trying to answer questions or looking for solutions to problems. It is just as important to come up with the *right* questions or to be able to correctly formulate the problems. And in the area of developmental studies, robots are extraordinary instruments for doing just that. In seeking to put together a development model for a robot, one is forced—just as with a purely mathematical or algorithmic model—to clearly articulate all of the hypotheses and all of the mechanisms that enter into it. Moreover, since the robot interacts with physical reality, one immediately sees whether these hypotheses and mechanisms "function" in this reality. This interactive process is essential and often brings out problems that are not identified in the theories formulated by biology or the social sciences, which often remain verbal, descriptive and non-integrative. For example, the role of spontaneous exploration in the perceptual and motor development of children has long been recognized and is now practically taken for granted in the vast literature on developmental psychology. But how does this spontaneous exploration work? What starts it off? What is it that makes an object or an activity interesting to a child? What is curiosity? How does the brain "measure" what is "interesting"? It is the same with language acquisition: we know that babbling, for example, plays an important role. But why do babies babble so much, even when they are alone and long before their vocalizations are useful for speech?

Satisfactory answers to these questions cannot be found in any of the scientific literature that exists today because these questions have never really been formulated in any precise way. When one is attempting to build a robot that is able to learn and develop, these questions naturally arise and become concrete. And in order to make the robot "function," one has to come up with mechanisms such as those that model curiosity by maximizing progress in learning.

Although we can test the way these robotic models interact with physical reality, they are still nothing more than hypotheses, points of departure whose purpose is to provide us with a better understanding of child development. For example, since they are actual, concrete forms, they enable scientists from the various disciplines that are concerned with this issue to communicate in an effective way. These models are in fact a new sort of language—objects that combine mathematics, algorithms and a physical substrate—that allows scientists to focus on and discuss specific mechanisms rather than to expound with words that are often interpreted in different ways, such as "curiosity," "learning," or "emotion." As the models naturally evolve during these exchanges, the scientists' points of view converge and they gradually come to share these models that give meaning to their environment as well as to share the terms that are used for naming them. A new language is thus invented that enables the scientists to talk, for example, about curiosity.

Through their physical substrate, i.e. their embodiment, and their "situatedness", these models also create crucial windows of interaction with non-scientists. Set up in public spaces, the *Flowers Fields* installation offers society new representations of the world and of what it means to be human, and in exchange, our scientific work is brought into contact with the hopes, fears and dreams of society. *Flowers Fields* stimulates its observers to ask questions about the nature of intelligence, language and life, with the hope that it will inspire curiosity in them, as well as the joy of learning and the joy of science.